Title Page
Department of Pesticide Regulation
Pest Management Grants - Final Report

Project Title: Using alfalfa to manage lygus bugs in cotton

Applicant: University of California, Division of Ag and Natural Resources

Agreement Number: **00-0218S**

Principal Investigators:

Dr. Peter B. Goodell Statewide IPM Project Kearney Agricultural Center, 9240 So Riverbend Ave, Parlier CA 93648	Dr. Charles G. Summers Dept. Entomology, UCD Kearney Agricultural Center 9240 So Riverbend Ave Parlier CA 93648	Dr. Shannon C. Mueller UC Cooperative Extension Fresno County 1720 Maple Ave Fresno CA
Telephone: 559/646-6515 Fax:559/646-6593 ipmpbg@uckac.edu	559/646-6575 559/646-6593 chasum@uckac.edu	559/456-7261 559/456-7575 scmueller@ucdavis.edu

Contractor Name: University of California, Division of Agriculture and Natural Resources
Contact Address: Ms Carol Berman
Contracts & Grants Coordinator
DANR, 3000 Lakeside Dr.
Oakland CA 94612-3550

Telephone: 510/987-0050 Fax: 510/987-6491 Email: carol.berman@ucop.edu

Date: 2/28/02

Prepared for the California Department of Pesticide Regulation

Aerial view of Field 75/76, Kearney REC with alfalfa strip treatments in place

Disclaimer:

Acknowledgements:

The investigators wish to acknowledge the dedication and work of UC employees who maintained plots, collected data, and summarized results. These include Mr. Albert Newton, Mr. Charles Haas, Ms Cecilia Garcia, Ms Susan Mallek, and Mr. Fasal Saleem.

This report was submitted in fulfillment of **00-0218S** *Using alfalfa to manage lygus bugs in cotton* by University of California Division of Agriculture and Natural Resources under partial sponsorship of California Department of Pesticide Regulation. Work was completed as of 2/1/02.

Mr. Albert Newton suction sampling cotton adjacent to alfalfa trials

Dr. Peter Goodell collecting lygus bugs for marking in the 38° F cold box

Mr. Chuck Haas conducting ELISA procedures on insects Collected from alfalfa fields to determine if they were marked before cutting

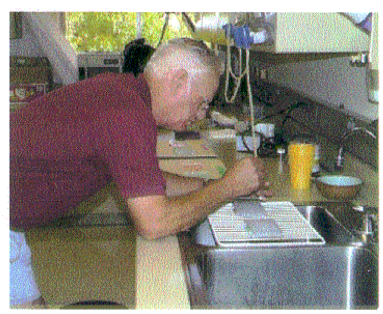


TABLE OF CONTENTS

EXECUTIVE SUMMARY

This project was designed to evaluate the practice of providing uncut alfalfa strips as alternative habitat for lygus in order to prevent lygus bugs from moving into other crops. We had three objectives

1. to compare the lygus populations in two strips, one that represented 2.5% of the field area and the other representing 10% of the field area, and in cotton borders next to the alfalfa trial
2. to understand lygus movement within and adjacent to the alfalfa strips
3. to evaluate the influence on hay quality when old and new hay is blended.

Three field sites (replicates) were established at Kearney Research and Extension Center in April 2001. These consisted of an alfalfa hay field with 16 rows of cotton planted on each end. Treatments consisted of an uncut strip 2.5% or 10% on each half of the field. Alfalfa cuttings occurred approximately every 28 days. Four cuttings were made during this trial on June 6, July 5, August 2 and August 30.

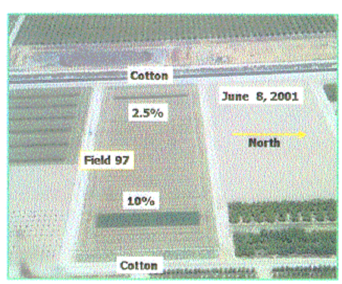
Using a D-vac, lygus adults were sampled in the alfalfa 48 hours prior to cutting and in cotton just before the alfalfa field was cut. Lygus were sampled from the uncut alfalfa strips and from cotton at 4, 8, 24 and 48 hours after cutting. There were significant differences in lygus populations between alfalfa hay and cotton at all the times sampled. Lygus populations remained below critical treatment thresholds in the cotton. There were no differences in adult lygus populations in 2.5% and 10% uncut areas, except on August 30 at all sampling times and July 5 at the 8-hour sampling. In those cases, 2.5% strips had a greater number of lygus adults than the 10% strips. In all cases, populations did not differ after 48 hours, which suggests there is a limit to crowding that lygus will tolerate.

In order to understand the movement within the field and out to the cotton borders, lygus were marked, released and recaptured. Vertebrate proteins were used as markers. The insects from the 2.5% uncut strip treatment were marked with chicken protein and insects collected from the 10% treatment were marked with rabbit protein. Marked insects were placed back into the field 48 hours prior to cutting. The insects collected from the uncut strips at the 4, 8, 24 and 48 post-harvest samplings were preserved in the freezer until a double-sandwich ELISA could be conducted. Only the June harvest has been completed. We found some movement of lygus between the 2.5% and 10% strips but no more than 8% of the population moved. The movement was greater from the area of the field that had 2.5% uncut hay remaining.

On three other fields, at each harvest, old and new hay were successfully blended. Bales consisted of 100% 28-day alfalfa, 75%:25% 28 vs. 56-day-old alfalfa, 50%:50% blend, and 100% 56-day-old alfalfa. Sample bales from each blend were removed for quality testing. All bales have been sampled, samples were submitted to a laboratory, and analyzed. A qualitative, visual inspection by a qualified hay expert was conducted. Both lab and visual inspection indicated significant differences in quality between bales containing new or blended hay.

Leaving uncut strips in alfalfa can help limit the movement of lygus into neighboring crops. However, the effect on hay quality must be considered. Future trials will evaluate the value of smaller but more numerous strips to maintain the value of habitat preservation and hay quality.

Aerial view of Field 97 at Kearney REC on June 8, 2001 showing alfalfa strip treatments and cotton sentinel crop on edge. Alfalfa strips on the field to south is one site of hay quality trial.



REPORT

Introduction

Regional management of insect pests has long been a goal of IPM. *Lygus hesperus* (Knight), with its wide host range of 328 plants (Scott, 1977) is a candidate for such a management approach. Lygus population development primarily occurs within the existing crop mosaic of the San Joaquin Valley (SJV). Its movement from one crop to another is dictated by the production practices within that crop. Lygus move into a crop, reproduce and are forced to move when the crop becomes unsuitable as a host. Lygus have a wide host range but do exhibit some host preference, especially for legumes. They are recorded pests on cotton, blackeye bean, seed alfalfa, lima bean, peach, nectarine, strawberry, apple, pear, celery, tomato and pistachio (IPM Guidelines, www.ipm.ucdavis.edu). This approach seeks to prevent lygus movement into cotton by providing an alternative and preferred host. The goal of this project is to enhance the knowledge base surrounding alfalfa as a key crop for regional management of lygus.

Alfalfa has long been recognized as a key component in the SJV cropping landscape (Stern et al., 1967; Rekickus and Watson, 1974; Summers, 1976, Godfrey and Leigh, 1994). It provides an insectary by acting as both refugee and nursery for many important natural enemies to cotton insect pests. It also acts as a sink for lygus movement providing a stable habitat, while suffering no economic loss from lygus feeding. It is the only widely grown crop that is maintained in a vegetative state and not allowed to senesce.

Proper alfalfa management can minimize the movement of lygus into cotton and can perform as a reduced-risk approach by:

- reducing the need for organophosphate and carbamate insecticides
- reducing the exposure of workers entering the fields
- increasing the complexity of the cotton IPM system by "stepping up" into higher levels of ecosystem management (e.g. from the field to the farm and region)

Importance of pest

Lygus hesperus is the key insect pest in SJV cotton production. It is an invasive pest, moving into cotton fields as other hosts become unsuitable. Cotton is most vulnerable during the early period of fruit production (May-June) when lygus can migrate in large numbers from native vegetation. However, the most common source of lygus is fields that surround cotton and are being prepared for harvest. These include safflower, seed alfalfa, tomatoes, sugar beets, alfalfa hay, and other fields with weed hosts. Thus, a cotton field may be in a biological balance one day but out of balance the next due to an event external and not of the farmer's making.

During the 1990's, lygus is estimated to have caused an average yield loss of $18,789,254 or 1.88% of the total production value (Williams, 1991-2000). UC guidelines call for cotton fields to be sampled twice weekly. Populations are estimated using a 38" sweep net and decisions are made based on lygus density, presence of nymphs (immature) and fruit retention (IPM Cotton Manual, IPM Cotton PMG, Insecticide Resistance Management Guidelines for Cotton). If the population has reached an economic level, chemical intervention is the only option. Insecticide choice is based on:

- time of year (avoid early season broad-spectrum to protect developing natural enemies)
- severity of migration - if the movement is a single pulse or there is a low persistent level, organophosphates or carbamates are suggested (these have somewhat less impact on beneficial and single applications do not aggravate aphids); if the movement is large and sustained, pyrethroids are suggested because of their residual control (although insecticide tolerance is reducing the length of residual period)
- the degree of pressure by other pests at the time of application including aphid, mites, worms, and whiteflies.

Priority criteria

Mitigating or preventing the arrival of lygus can enhance the reduced-risk environment. First, avoiding, delaying, or reducing the movement of lygus into cotton will reduce the need for applications of organophosphates (acephate, dimethoate, methamidophos, and methidathion), carbamates (aldicarb and oxamyl) and pyrethroids (bifenthrin, cyfluthrin, cypermethrin, esfenvalerate, lamda cyhalothrin or zetacypermethrin). A reduction in the use of broad-spectrum materials could reduce secondary pest outbreaks and further reduce the need for organophosphates and restricted use materials against aphids and worms. In addition, a reduction in the use of these products should provide an additional margin of safety to workers having to enter the field for irrigation, weed control or scheduled scouting inspections.

Importance of proposed practice

Management of lygus is limited to broad-spectrum insecticides including organophosphates carbamates, and pyrethroids. The exceptions are imidocloprid (Provado) and indoxacarb (Stewart) that are suggested for use against low populations or limited migrations. Currently there are no reduced risk materials available or cultural techniques such as host plant resistance, or augmentative biological control. Management of alfalfa has been recognized as a valuable tool in preventing migration of lygus, but has been limited in its general adoption due to a lack of data supporting efficacy and concerns about hay quality. IPM could be moved to the next level of organizational complexity (from individual field management to the landscape management) if a community-wide effort could be mounted to mitigate lygus movement through the management of alfalfa, Growers across a wide area could realize the benefits through the reduced need to treat migrating lygus populations.

Integration into system

This project provided additional evidence about the value of incorporating alfalfa management in a farm or area wide lygus management program. Even though strip and block cutting was suggested in 1967 (Stern et al), its adoption has been limited by the complexity of managing pests in multiple crops, especially those crops not affected by the insect. Within a farm, many farmers have used the approach but where the alfalfa is outside the purview of the cotton farmer, neighbors must be convinced of its value. Our studies provided further data by detailing the population dynamics of lygus in alfalfa during cutting. The additional information on the movement of lygus in and around our alfalfa study sites will support the case for an area wide approach.

A limitation to acceptance of stripping hay has been the concern by alfalfa hay producers about the quality of hay when old growth (56-day old) is mixed with new hay (28-day old). Concerns about nutritional quality (TDN) and palatability may have slowed the adoption rate, especially for hay destined to dairies The issue needs to be clarified through bale sampling for qualitative and quantitative forage analysis. If stripping hay does create quality problems, management approaches of hay from the strips should be devised.

Importance to community

Lygus is the key pest in SJV cotton. The industry has placed lygus management as a high priority. As the management of lygus goes, so goes all cotton pest management. Growers see this pest as an early threat to yield and potential earliness. The cotton plant can compensate for loss of early fruit, but growers are unwilling to risk early loss of fruit in the hope there will be time to develop new fruit and still have a timely harvest.

Thus, any technique that reduces the grower's exposure to lygus risk, especially early, would be deemed important. Lygus management has been identified as a high priority through a series of stakeholders meetings beginning in 1995 and revisited annually (Goodell et al., 1997).

Objectives

Objective 1. To evaluate modified strip-cutting alfalfa as a method for limiting lygus bug movement into cotton.

Tasks:

1. Develop replicated experiments at Kearney Research and Extension Center KREC).
2. Create two habitat treatments in which one half of the field has 10% of the alfalfa left uncut and the other half, 2.5% of the alfalfa uncut.
3. Plant cotton at the edge of each field to act as sentinel crop.
4. Sample alfalfa and cotton for lygus before cutting and sample uncut alfalfa strips and cotton 4, 8, 24, 48 hours after cutting.
5. Collect lygus and preserve in freezer until they can be counted.
6. Summarize and analyze data.

Objective 2. To investigate the inter and intra field movement of lygus when alfalfa strips are retained

Tasks:

1. Using the insects collected from pre-cut sample, mark with two different vertebrate proteins and return to field.
2. The post-cut samples will be stored in the freezer until they can be analyzed for the presence of the vertebrate proteins using double-sandwich ELISA methods.
3. Summarize and analyze data.

Objective 3. To evaluate the influence of different aged alfalfa on hay quality

Tasks:

1. Select three fields at Kearney REC to conduct research.
2. Work with field staff to cut, rake and bale hay to achieve blended hay treatments of 100%:0, 50:50%, 75:25%, 0:100%, new (28 day old alfalfa) to old hay (56 day old alfalfa)ratios.
3. Collect samples from bales of each treatment and submit to analytical laboratory for analysis.
4. Place sample bales from each treatment and cutting into storage for evaluation by hay buyer.

Methods and Materials:

The trial was conducted at Kearney REC on three alfalfa fields. Each field represented a replication. The experiment was repeated four times with alfalfa harvest occurring on June 6, July 5, August 2 and August 30. For each replication, a treatment was randomly assigned to each half of the field. Treatments were 10% of the alfalfa left uncut or 2.5% of the alfalfa left uncut. A single uncut strip was left (Figure 1). At each end of the field, 16 rows of cotton (CPCSD Acala cotton, "*Rialta*") were planted on April 28, 2001.

Forty-eight hours prior to each cutting, the alfalfa was sampled for lygus to estimate the field population density. A sample consisted of five 15-second suctions using a D-vac suction sampler, covering an area of five square feet. Pre-harvest samples were collected down the length of the alfalfa field from 12 representative areas of the field (Figure 2). The contents of the D-vac were taken to a 38° F cold room to slow lygus activity. Adults were counted and categorized by gender. Lygus were placed in a vial and marked with either rabbit protein or chicken protein, depending on which half of the field they came (10% or 2.5% treatments, respective). The insects were returned to the sample area in which they were collected. After the June cutting, three samples were also taken from each of the uncut strips prior to the next cutting.

On the day of cutting, the cotton sentinel crop was sampled by taking three samples down the length of the cotton strip with the suction sampler as described for alfalfa. These insects were frozen and counted as described. The uncut alfalfa strips and cotton were sampled 4, 8, 24, and 48 hours after cutting.

The number of lygus adults collected from three sub-samples per alfalfa strip or cotton was averaged and this mean total number was used for the analysis. Total number of adults collected in five-square feet was analyzed as four individual trials (date of cutting) with multi-factor analysis of variance using crop (cotton or alfalfa) and treatment (2.5% or 10% strip left uncut) as main factors. To examine whether one treatment accumulated lygus adults at a different rate, the slopes of accumulated counts over 48 hrs were compared for differences.

After counting, the insects were placed in labeled Petri dishes and returned to the freezer until they could be analyzed using ELISA. The purpose of the marking and subsequent ELISA analysis was to understand the movement of lygus between strips. The insects were individually prepared and subjected to a double-sandwiched ELISA (Haglar et al., 1992; Haglar, 1997) to identify any marked insects. Each insect collected required two ELISA tests, one for rabbit protein and one for chicken protein. A microplate reader (Thermo Max, Molecular Devices, Inc.) was used to read the ELISA plates and results placed directly into computer data files. These files were processed and summarized as percent of insects originally marked as 2.5% that were actually recovered from 10% strip and vice versa.

Bales with various compositions of old and new growth were created in the field during the swathing and raking process (Figure 3). The term "old" hay refers to the hay from the previously uncut strip, approximately 56 days old at harvest, and the "new" hay is alfalfa that has grown only since the last cutting, usually in a 26-28 day period. If the swather cuts the entire "old" strip, and it is maintained as a single windrow during raking, bales from that windrow will contain 100% old hay. Likewise, if a previously uncut strip ("old" hay) is completely avoided during swathing and raking, the bales from those windrows will contain 100% new hay. To create the 50/50 blend of old and new hay, the swather divides the previously uncut strip in half. Therefore, two adjacent windrows each contain 50% old and 50% new hay. They can be raked together into one large windrow, retaining the 50/50 composition at baling. To create bales composed of 25% old hay and 75% new hay, the strip of "old" growth is again split in half by the swather. The two resulting windrows are a 50/50 blend of old and new growth. Instead of raking them together, they are raked with an adjacent windrow of 100% new growth so the resulting windrow is a mixture of 50/50 and 100% new hay, creating a final bale composition of 25% old / 75% new.

Bales from three cuttings each year and four "composition" treatments were randomly selected and stored in individual stacks (4-8 bales each). They were stored uncovered.. Within the first two weeks of storage, all bales within a stack were sampled using a Penn State coring device and electric drill. Bales were probed at the end of the bale near the center, penetrating at least 12-18 inches into the bale. The probe was held at a right angle to the bale end. A minimum of eight cores per stack was composited and placed in a sealed zip-lock bag. Samples were stored at room temperature, light, and humidity until the end of the season. Each sample was analyzed for moisture (dry matter), crude protein (CP), and acid detergent fiber (ADF) (Bath and Marble, 1989; Putnam and Orloff, 2000). Total Digestible Nutrients (TDN) and Net Energy for Lactation (NEL) were calculated using the measured ADF values. Bales remained in storage until quality was evaluated in the fall by an independent hay broker/animal nutritionist based upon visual examination.

Results:

Objective 1.

Data were successfully collected on four alfalfa harvest dates, June 6, July 5, August 2 and August 30. On July 7, 2001, a rain event prevented the collection of the 48 hr post-harvest sample. A total of 810 individual samples were taken during this experiment. There were significant differences in adult lygus populations between the cotton and the uncut alfalfa strips at each cutting (Figure 4). Between the alfalfa strips, there were no significant differences in adult lygus population at any sample period except on August 30, 2001 and during the eight-hour sample on July 5 (Figure 4 and 5). The population density in the alfalfa strips were similar after 48 hours (Figure 6) and increased by six-fold over pre-cut counts (Figure 7).

Objective 2:

Processing samples through ELISA required far more time then projected. Between each cutting, the 8-hour samples were analyzed. Only one cutting date (June 6, 2001) has been completely analyzed. A second date is currently 50% completed. The June sample indicated that the mark-release-recapture technique works. However, for every insect captured, two ELISA procedures must be conducted, one to look for rabbit markers and the other to look for chicken protein markers.

The June cutting data indicated that more lygus moved out of 2.5% uncut strip than out of the 10% uncut strip (Figure 8). However, only 8% of the total population in the 10% strip originated from 2.5% strip

Objective 3.

The hay quality experiment was conducted on three cutting dates, June 6, July 5 and 6, and August 30. The individual hay quality parameters are reported.

Dry Matter

Dry matter (DM) is used to determine the amount of water in hay or silage. Most hay is sold on a 90% DM basis. Dry matter affects only tonnage, not forage quality. However, extremely low moisture could indicate brittleness or excessive leaf loss and high moisture could indicate the potential for mold growth.

There was no significant effect of forage composition on the dry matter content of the hay in either year (Table 1). There were significant differences in the moisture content of samples from the different harvest dates in 2000 and 2001. In both years, samples from the June cutting had lower average moisture content than samples from the later cuttings.

Crude Protein

Crude protein (CP) is calculated from the nitrogen content of the forage. The majority of the protein is found in the leaf fraction. Protein contributes energy and provides essential amino acids to the animal that consumes the forage. The more protein that comes from the forage, the less the ration must be supplemented to provide for animal requirements.

As the percentage of older hay in the bale increased, crude protein values declined significantly, as would be expected due to the increased proportion of mature, more fibrous stem tissue and lower leaf content (Table 1).

Acid Detergent Fiber

Acid Detergent Fiber (ADF) consists primarily of lignin and cellulose located in the cell walls of plants. As alfalfa matures and the stems become more lignified, ADF values increase. The rate of maturation increases with increasing temperature during the growth cycle. ADF has a strong negative correlation with total forage digestibility. As ADF increases, forage quality declines as evidenced by reductions in both intake and digestibility.

Date of harvest and composition of the bale both had significant effects on the fiber content as measured by acid detergent fiber analysis. Fiber values were highest in July (36.7%), followed by August (33.9%) and June (31.9%). Since all cutting intervals were 27-28 days, the timing of high summer temperatures probably contributed more to the effect on fiber values.

ADF values followed the expected pattern with respect to composition of the bale, that is ADF values increased significantly as the percentage of old hay in the bale increased (Table 1).

Total Digestible Nutrients and Net Energy of Lactation

Total Digestible Nutrients (TDN) and Net Energy of Lactation (NEL) are calculated from ADF and are used to estimate the energy value of forages. The equations can be found at the bottom of Table 1. Hay in California is most often bought and sold based on its TDN value, especially in the dairy market. Hay with a TDN value greater than 55.9% (at 90% DM) is designated as Extra Premium, and is quite desirable for high producing dairy cows. Premium quality hay has a TDN value between 54.5 and

55.9%, and is also quite desirable. Good quality hay is defined by having TDN values between 52.5 and 54.5%. If hay tests between 50.5 and 52.5% TDN, it is designated as fair quality and would not be suitable for dairy animals. However, this does not mean the hay is not marketable. There are many other markets for hay with TDN values below dairy quality standards, such as beef and horse markets.

NEL estimates the energy in forage available to support an animal's energy requirement for lactation. It is most often used for balancing dairy cattle rations. The purpose of hay quality guidelines incorporating estimates of TDN or NEL is to help promote a common language for trading hay, and to aid in the understanding of forage quality. Designations are based upon historical experience and the biological relationships between hay quality and milk production.

Based upon TDN, the average quality of alfalfa in this trial was below fair in 2001. On average, even bales containing 100% new growth were rated as having only good or fair quality. Since the research station is not in the business of growing hay to meet the demand for high quality desired by the dairy market; the cutting interval is longer and quality is generally lower. However, relative differences in quality between the various composition treatments gives an indication of what can be expected if a grower blends the old forage with new growth.

Visual Evaluation of Quality

Predicting forage quality is not an exact science. Both visual inspection and laboratory analysis provide clues as to the potential feeding value of hay. These techniques are best used in combination because there are certain characteristics that cannot be evaluated by chemical analysis, such as the presence of weeds, mold, and physical problems, and the reverse is also true, it is impossible to determine crude protein content by simply looking at the hay. For that reason, in this trial, an independent consultant rated the hay on a variety of visual characteristics. All ratings were made on a single day to limit variability (10/11/01).

Timber

This rating describes the "hardness" of the stack and ranged from 1 to 5, with 1 = hard and 5 = soft. Individual stacks were evaluated by striking them with the side of a closed fist. There was no significant difference in the timber of the stacks from individual cuttings or bale composition treatments. All average values were between 1.8 and 2.3 on the 5-point scale. Only one bale stood out with a 3.5 timber rating. It was harvested in June and contained 100% new growth hay.

Leaf Quality

Leaf quality was significantly influenced by the cutting cycle. June-harvested bales had a significantly higher leaf quality score (1.9) than the July-harvested bales (2.6). August-harvested bales fell in between, scoring 2.4. Average leaf quality scores for the individual bale composition treatments ranged from 2.0 to 2.5, and were not significantly different from one another (Table 2).

Rain Damage or Heavy Dew

The rating scale ranged from 1 = no effect from rain or heavy dew to 5 = extensively damaged. This score was only influenced by harvest date. The June-harvested bales had an average score of 1.5 while the July- and August-harvested bales had average scores on 2.3 and 2.1, respectively (Table 2).

Insect Damage

Damage to leaf and stem material from insects was evaluated by visual inspection of the flakes within the bale. There were no significant differences in insect damage scores attributable to harvest or bale composition. The level of insect damage was very low in most cases. Only two bales fell outside of the 1-1.3 scoring range that indicated no evidence of insect damage. One scored 2 and the other scored 3. One was harvested in June and contained 100% old growth while the other was harvested in August and contained 100% new growth (Table 2).

Aroma

There were no significant differences in the aroma of the hay in the individual stacks as a result of harvest date or bale composition. Average values were between 2.2 and 2.5 on the three harvest dates, and between 1.9 and 2.8 for the individual bale compositions. Only one bale was noted to have a particularly bad odor. It contained 100% old growth and was harvested in August. It received a score of 4 on a 5-point scale (Table 2).

Discussion:

Alfalfa has been demonstrated to have a beneficial effect on holding lygus bugs. This crop is the only widely produced commodity that is grown for its vegetative rather then its reproductive components. A lygus population developing on alfalfa does not suffer through a senescing period in which the status as a favorable host degrades. When the alfalfa is cut, the insects are well fed with little need to move from the field, except for temporary shelter and shade.

These trials demonstrate that leaving alfalfa strips is useful in providing habitat for a large number of lygus. The uncut strip representing 2.5% of the plot accumulated lygus at a faster rate than the 10% strip, but after 48 hrs, both strips held similar population densities (Figures 4, 5 and 6). The population density after 48 hrs ranged from 30 to 90 adults per 5 ft^2 and increased over the initial field population from 4-fold to 7-fold, depending on the cutting date (Figure 7). Considering that the initial population density was around 10/5 ft^2 at each cutting date, it is unclear why the final density varied between cutting dates. This variation between cutting dates may be an artifact of sampling or it may represent true population differences through time. For any cutting date, the population on the two strips leveled at the similar densities (Figure 6).

Regardless of the final population, we were able to increase the density many times over pre-cut levels. Lygus were reluctant to move out of alfalfa as long as they had some habitat in which they could reside. Our results do not indicate a large movement into adjacent cotton (Figure 4). We were unable to detect any significant increase of lygus in cotton at 4, 8, 24, or 48 hours after cutting but found significant differences between alfalfa and cotton, with lygus preferring to remain in alfalfa.

To be sure that the D-vac was catching lygus at a rate similar to a sweep net (the commonly used sample device in cotton), we sampled cotton concurrently with a sweep net. There was a significant relationship between D-vac and sweep samples at the $P<0.1$ but only 19% of the variation could be explained (Figure 9). Since cotton has completely different canopy architecture than alfalfa, the sampling efficacy could be expected to be different between the crops. The sweep net indicated that the population was not at levels to warrant treatment and provides confidence that the D-vac suction sampler will detect populations that could result in crop loss.

The marked insects exercise demonstrated that lygus did not fly in large numbers into adjoining plots (Figure 8). This indicates that they remained close to their origins with only 8% of the population in June leaving to go into the adjoining plot. These studies left the uncut alfalfa as one strip. Realistically this strip should be spread through the field to decrease the distance that an insect must travel and to reduce the amount of "old" hay that needs to be blended into new hay, as suggested by Summers (1976).

Alfalfa growers recognize the importance of producing a high quality product, both in terms of appearance and nutritional value. Quality has a profound impact on animal performance and consequently the price or value of alfalfa hay. There were clear-cut negative impacts of mixing old hay with the new growth alfalfa in 2001. As old growth was added in 25% increments to the new forage in the bale, crude protein values declined by approximately 1%. ADF values also increased significantly when alfalfa from previously uncut strips was mixed with newly harvested forage. Seasonal, or cutting cycle, effects were also detected each year, but there was no interaction between cutting cycle and bale composition effects. Since ADF is used to calculate TDN, the basis of marketing, it will have a significant impact on the value and marketability of the forage. In these trials, about 1 percentage point TDN was lost for each addition of 25% old growth. In a typical California dairy market, blending 50% of the old growth with 50% new forage could mean a reduction of 2% TDN. This could mean a significant difference in the selling price if the alfalfa dropped from the premium category to the fair category. However, there are other markets less sensitive to such changes in TDN, where buyers base decisions on a combination of visual and chemical characteristics, and such hay would not be difficult to sell there.

Reductions in laboratory-measured quality values as old growth alfalfa was blended with new growth were consistent over the two years that this study was conducted. However, the effect of altering bale composition on visual appearance of the bales was less clear cut. Some of the negative affects of blending old with new hay may have been masked by differences in management of the fields or environmental conditions during the individual cutting cycles..

When evaluating hay, there appear to be subtle changes in the appearance of bales when old growth is blended with new growth that can be detected during visual examination. The most sensitive characteristics appear to be color and overall quality. Growers need to assess the requirements of their market, and determine the best strategy for managing the alfalfa strips left in fields for the purpose of lygus management. If the majority of the field produces hay suitable for the dairy market, it may be best to segregate bales from the uncut strips and market them separately. Alternatively, if the balance of the hay is not destined for the dairy market, blending the old growth with new growth, at a maximum of 25% to 50%, may be the most efficient strategy to handle the forage from the uncut strip. It would be interesting to evaluate the management strategies described here with equipment for making large square bales. Blending the old growth with new growth may not be as easily detected by laboratory analysis or visual inspection in a large bale system. Another approach would be to reduce the size of strips by having smaller strips spread through the field and decrease the percent of old hay being blended.

Summary and Conclusions:

This project supports the role of alfalfa as a key crop in lygus management. Since alfalfa is not affected by lygus, it can act as a sink for lygus from the surrounding area. Our studies show that we can increase the population density of adult lygus in an uncut strip by a factor of six. Our results indicate that regardless of the size of the strip, an upper level of population density can be reached. We found that lygus will not move into cotton in numbers that threaten the crop and lygus adults did not travel in great numbers (only 13% of the population) across the field to reach the larger strip.

We found that a 25% blend of old hay with 75% new hay was enough to negatively impact quality. A balance between providing habitat for lygus and maintaining quality hay must be found. Further research is needed to achieve this balance including the use of numerous strips spread across the field as suggested by Summers (1976), exploring the role of neighboring hay fields as equivalent habitat, developing a management system based on hay abundance that directs the need for strip habitat preservation and evaluating more susceptible hosts such black-eye beans in additional to cotton in close proximity to alfalfa strips.

Providing habitat for lygus and preventing them from moving into susceptible crops still remains one of the best approaches in developing a reduced risk environment and enhancing a bio-based IPM system for cotton.

Appendices – Figures 1 to 8
Tables 1 and 2
References

Figure 1. Field plot design and layout of alfalfa and cotton fields to measure lygus movement during hay harvest. Three separate fields (replication) were used.

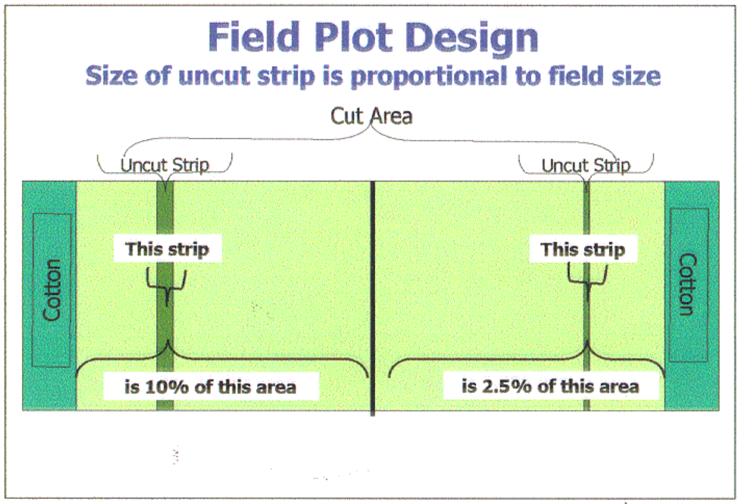


Figure 2. Lygus sampling plan in alfalfa and cotton trial using a suction sampler. A sample consisted of five 15-second suctions, represented by five circles in square 12.

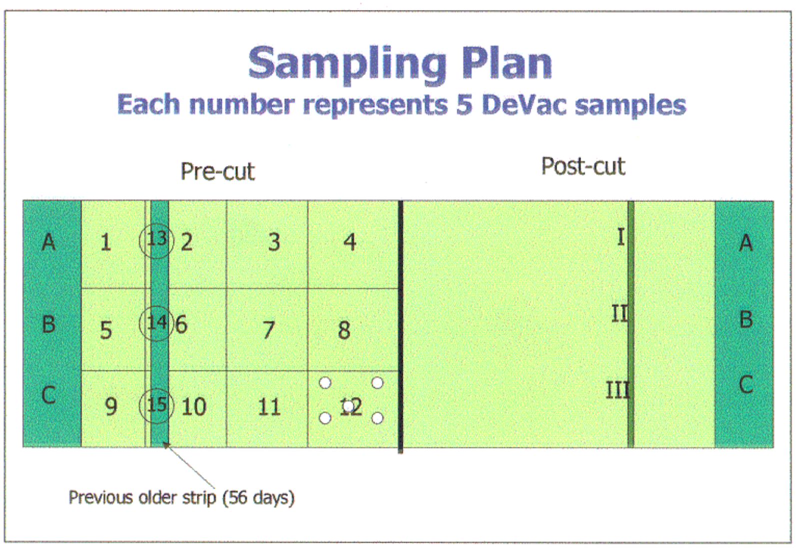


Figure 3. Swathing and raking pattern used to create bales of various compositions.

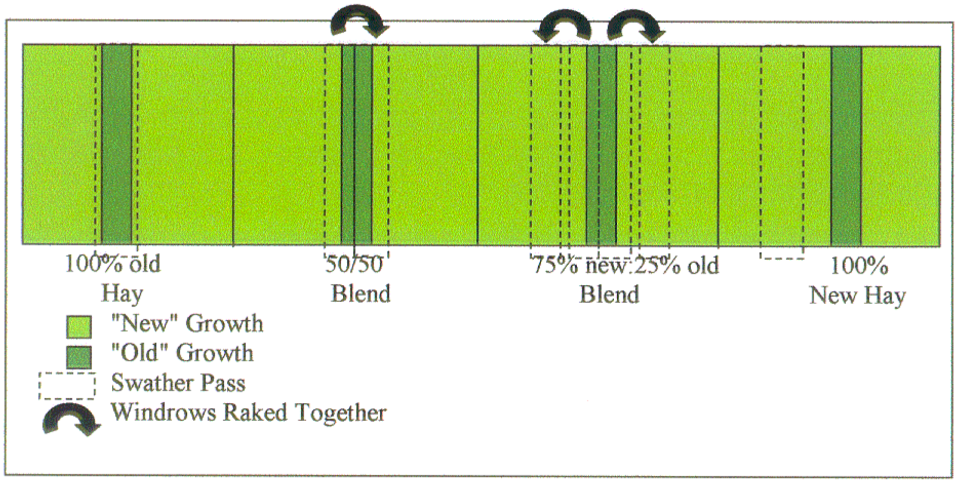


Figure 4. Lygus adult population densities in cotton and alfalfa strips 0, 4, 8, 24 and 48 hours after alfalfa harvest. No data were taken at 48 hrs on July 5 due to rain.

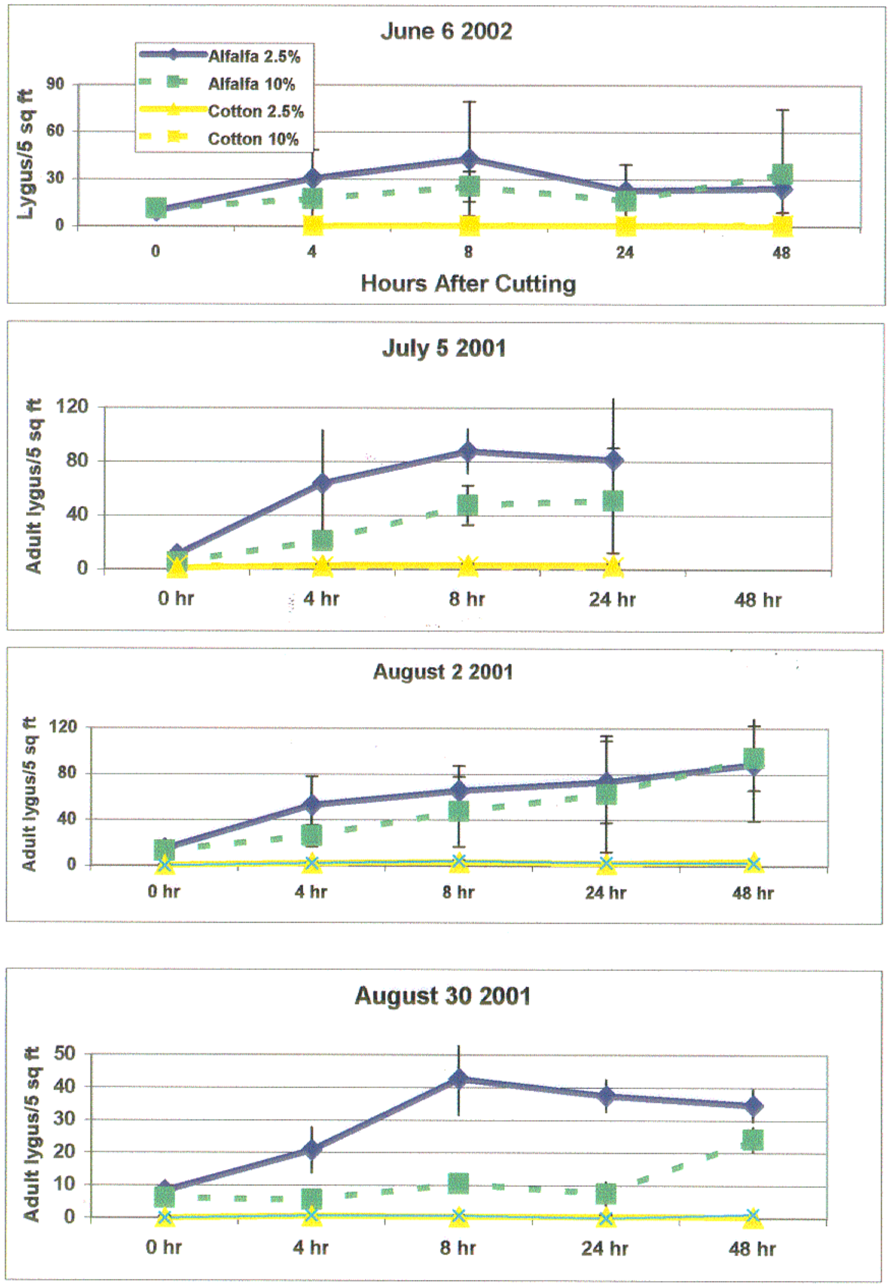


Figure 5. Cumulative population density of lygus adults in alfalfa strips over four cuttings at KREC in 2001. Except for August 30, 2002, there is no significant difference in the buildup of population. Slopes are not different (P<0.05).

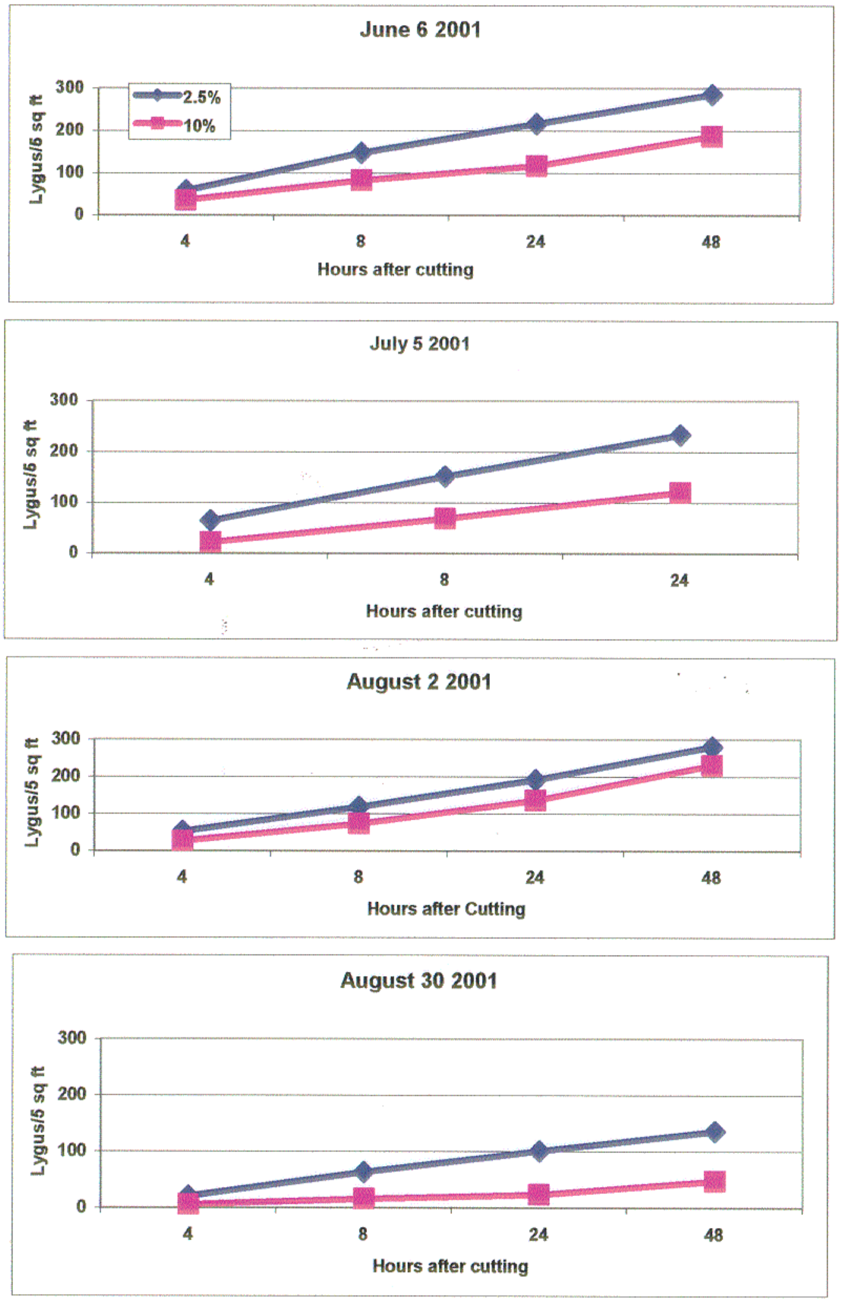


Figure 6. Population densities in two alfalfa strips (2.5% and 10% of total area) 48 hours after cutting. Forty-eight hour sample for July 5 was lost due to rain.

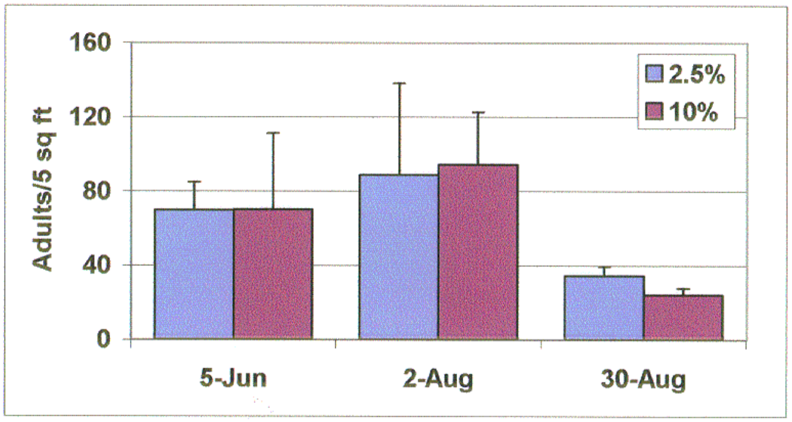


Figure 7. Population increase of lygus adults 48 hours after cutting in two alfalfa strips (2.5% and 10% of total area).

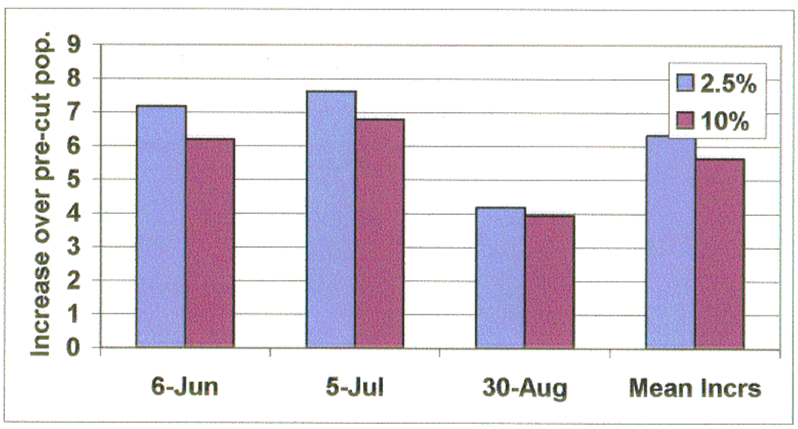
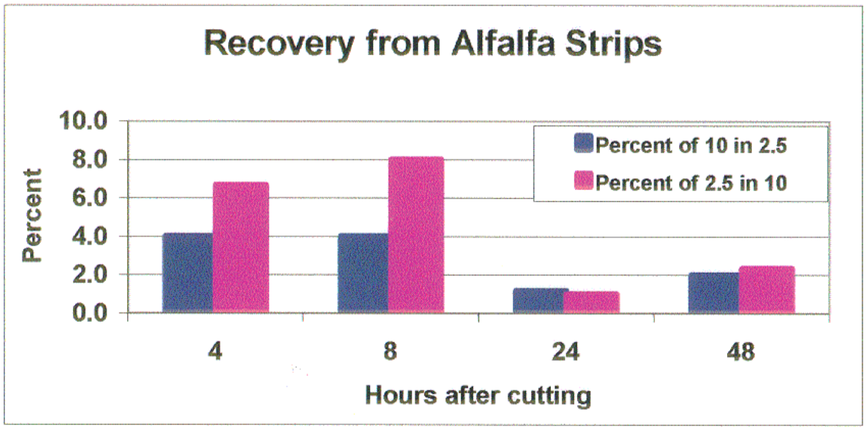


Figure 8. Movement of lygus adults between uncut alfalfa strip treatments, 2.5% uncut or 10% uncut. Data are from uncut alfalfa or cotton borders for June 6, 2001 harvest and represent the percent of marked individuals found in the adjacent treatment.



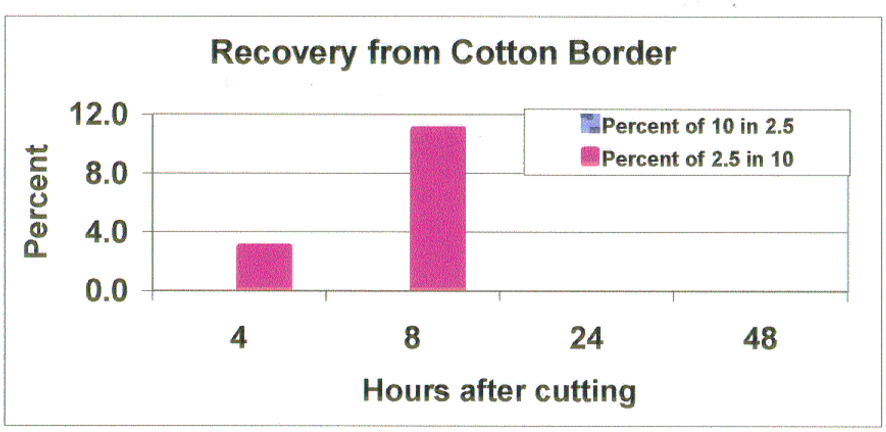


Figure 9. Relationship of lygus catch between sweep net and D-vac suction sampler in cotton July, 2001 at Kearney REC. While the P-value in the ANOV is significant at 10%, the r^2 explains only 19% of the variation.

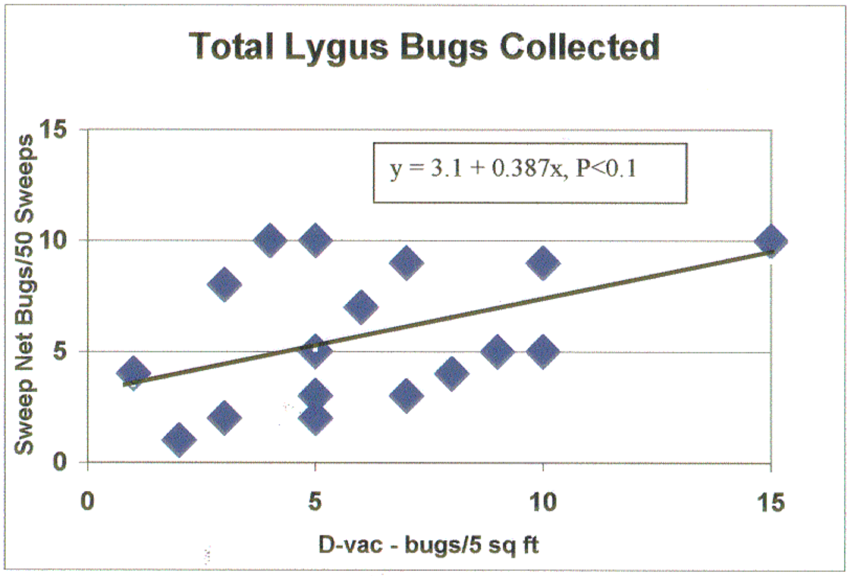


Table 1. The influence of bale composition on selected quality parameters as determined by chemical analysis.

Bale Composition	Percent Moisture	% Crude Protein	ADF (%)	TDN (%)	NEL Mcal/lb	Dairy Quality
100% New Hay	9.8	20.0 a	31.2 c	50.7 a	0.57 a	Fair
25% Old/75% New	9.9	18.8 b	33.3 b	49.1 b	0.55 b	Below Fair
50% Old/50% New	10.4	17.7 c	34.4 b	48.3 b	0.54 b	Below Fair
100% Old Hay	9.6	16.1 d	37.9 a	45.7 c	0.51 c	Below Fair
p-value (0.05)	*ns*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	

CP, ADF, and TDN are reported at 90% DM. NEL is reported at 100% DM.
TDN = 82.38 - (0.7515 X ADF)
NEL = ((0.0245 x TDN) - 0.12)/2.204

Table 2. The influence of cutting and bale composition on selected quality parameters as determined by visual analysis.

Cutting	Leaf Quality	Rain or Dew	Moisture	Color	Overall Quality
June	1.90 a	1.52 a	9.74 a	1.85 a	2.00 a
July	2.60 b	2.27 b	10.13 a	2.88 b	3.15 b
August	2.42 ab	2.06 b	11.46 b	2.60 b	2.71 b
p-value (0.05)	*0.0302*	*0.0177*	*0.0018*	*0.0005*	*0.0034*
Bale Composition					
100% New Hay	2.03	1.67	10.39	2.22 a	2.42
25% Old/75% New	2.39	1.92	10.10	2.17 ab	2.31
50% Old/50% New	2.33	1.97	10.22	2.50 ab	2.58
100% Old Hay	2.47	2.25	11.06	2.89 b	3.17
p-value (0.05)	*ns*	*ns*	*ns*	*0.0446*	*ns*

Quality scale: 0-5,
0=good, 5=poor

References

Bath, D.L. and V.L. Marble. 1989. Testing alfalfa for its feeding value. WREP 109, Leaflet 21457. DANR Publications.

California Agricultural Statistics Service. 2000. Summary of Agricultural Commissioners' Reports. 1998-1999. ftp://www.nass.usda.gov/pub/nass/ca/AgComm/199908cavtb00.pdf

Godfrey, L.D. and T.F. Leigh. 1994. Alfalfa harvest strategy effect on lygus bug and insect predator population density: Implications for use as a trap crop in cotton. Environmental Entomology 23 (5):1106-1118.

Godfrey, L., P. Goodell, E. Grafton-Cardwell, N. Toscano, E.T. Natwick, and J. Brazzle. 1998. Insects and Mites. In: UC Pest Management Guidelines for Cotton Pests.
http://www.ipm.ucdavis.edu/PMG/selectnewpest.cotton.html

Goodell, P.B., E.E. Grafton-Cardwell, and L.D. Godfrey. 1997. Maintaining an IPM program in a shifting pest environment. 1997 Proceedings of the Beltwide Cotton Production Research Conferences. Vol. 2:1146-1148.

Goodell, P.B., L.D. Godfrey, E.E. Grafton-Cardwell, N. Toscano, and S.D. Wright. Insecticide and Miticide Resistance Management in SJV Cotton for 2001. ANR Publication 8033. August 2001. 23 pp.
http://anrcatalog.ucdavis.edu/pdf/8033.pdf

Hagler, J.R. 1997. Field retention of a novel mark-release-recapture method. Environmental Entomology 26 (5): 1079-1086.

Hagler, J.R., A. Cohen, D. Bradley-Donlop, and F.J. Enriquez. 1992. New approach to mark insects for feeding and dispersal studies. Environmental Entomology 21:896-900.

Putnam, D. and S. Orloff. 2000. Standardized recommendations for hay sampling. UCCE publication.

Ohlendorf, B.L.P. 1996. Integrated Pest Management for Cotton in the Western United States. DANR Publication 3305. Second edition.

Rekickus, R.J. and T. F. Watson. 1974. Population trends of *Lygus* species and selected predators in strip cut alfalfa. Environmental Entomology 3:781-784.

Scott, D.R. 1977. An annotated list of host plants for *Lygus hesperus* Knight. Bulletin of the Entomological Society of America 23:19-22.

Stern, V.R., R. Van den Bosch, T.F. Leigh, O.D. McCutcheon, W.R. Sallee, C.E. Houston, and M.J. Garber. 1967. Lygus Control by Strip Cutting Alfalfa. UC Agricultural Extension Service. AXT-241. 13 pp.

Stern, V.M., A. Mueller, V. Sevacharian, and M. Way. 1969. Lygus bug control in cotton through alfalfa interplanting. California Agriculture 23(2): 8-10.

Summers, C.G. 1976. Population fluctuations of selected arthropods in alfalfa: influence of two harvesting practices. Environmental Entomology 5:103-110.

Williams, M. 1990-2000. Crop losses caused by insects. Proceedings of Beltwide Cotton Production Conferences. http://www.msstate.edu/Entomology/Cotton.html